UHF Gen 2 RFID Speedway® Revolution

Installation and Operations Guide

Products Covered by this Guide

This guide pertains to readers that have the following part numbers:

Speedway R220 (FCC): **IPJ-REV-R220-USA1M1**
Speedway R420 (FCC): **IPJ-REV-R420-USA1M1**
Speedway R220 (ETSI): **IPJ-REV-R220-EU11M1**
Speedway R420 (ETSI): **IPJ-REV-R420-EU11M1**

Federal Communications Commission (FCC) Compliance

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Consult the dealer or a qualified radio/TV technician for assistance.

Caution Changes to this product or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate per FCC Part 15.

Industry Canada (IC) Compliance

Operation is subject to the following two conditions: (1) this device may not cause interference and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

This device has been designed to operate with the antenna(s) listed on page 28 that have a maximum gain of 6 dB. Antennas not included in this list or having a gain greater than 6 dB are strictly prohibited for use with this device. The required antenna impedance is 50 ohms. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that permitted for successful communication. The term "IC:" before the radio certification number only signifies that Industry of Canada technical specifications were met.

CE Marking and European Economic Area (EEA)

RFID devices designed for use throughout the EEA must have a maximum radiated transmit power of 2W ERP in the frequency range of 865.6–867.6 MHz. For other EEA restrictions on RFID device use, please refer to the Impinj Declaration of Conformity (DoC) located at http://support.impinj.com

Before You Begin

Warning: Please read this document in its entirety before operating the Speedway Revolution reader, as serious personal injury or equipment damage may result from improper use. Unauthorized opening of the Speedway Revolution reader enclosure voids the warranty.

To safeguard personnel, be sure to position all antenna(s) according to the specified requirements for your regulatory region. For details, see "Appendix A: Information Specific to Regions of Operation" on page 27.

Table of Contents

Chapter 1: Introduction

Welcome to the *Speedway Revolution Installation and Operations Guide*.

About this Guide

This guide provides detailed instructions on installing, connecting, configuring, operating, upgrading, and troubleshooting the Speedway Revolution reader. To minimize and streamline the information in this guide, its contents focus on the installation and operation of a single reader.

Intended Audience

This guide is intended for anyone who is installing a Speedway Revolution reader. The assumption, however, is that the primary users of this guide are systems engineers and IT personnel who have basic knowledge of and experience working in software development, hardware systems integration, and network connectivity.

In addition, it is assumed that the reader has a high-level understanding of RFID and RFID systems management as well as a basic familiarity with the EPCGlobal Gen 2 specification.

Other Documents of Interest

This guide is part of a larger documentation set that supports Speedway Revolution. The other documents are outlined below:

*   *Speedway Revolution Getting Started Guide*
    This one-page guide is included in the box with the Speedway Revolution reader. It provides basic information about the hardware as well as instructions for obtaining additional documentation, downloads of firmware upgrades, and other support software.
*   *Rshell Reference Manual*
    This guide, intended for anyone who needs to use the Speedway Revolution Rshell console, includes descriptions and syntax for the Rshell command language.
*   *Octane SNMP Guide*
    This guide, intended for anyone who needs to monitor the health of the installed readers, includes reference information for working with the SNMP MIBs related to Speedway Revolution (the standard TCP/IP networking MIB (MIB-II) and a subset of the standard EPCglobal RM MIB).
*   *Firmware Upgrade Reference Manual*
    This guide, intended for anyone needing to upgrade the firmware on the installed Speedway Revolution readers, includes detailed procedures and reference information for upgrading single readers and for creating a metafile to automate the upgrade of multiple readers.
*   *Impinj LTK Programmer's Guide*
    This guide, intended for software engineers, provides guidelines and best practices for working with the LLRP Toolkit. In addition to this guide, software engineers can access language-specific reference guides and sample applications illustrating the scenarios discussed in the Programmer's Guide.

- *Speedway Revolution Embedded Developer's Guide*
  This guide describes the Speedway Revolution platform and provides a high level view of its architecture. It is intended for software engineers who are designing custom application software that will run on the Speedway Revolution reader.

- *Octane LLRP*
  This guide, intended for software engineers, describes the LLRP capabilities supported by Speedway Revolution, including Impinj's custom LLRP extensions. Note that Octane is the name for the Speedway Revolution firmware.

Impinj Support Information

See the Impinj Support Web site (support.impinj.com) for information about obtaining technical assistance. For guidelines about how to capture data for analysis by Impinj technical support personnel, see page 25.

Introduction to Speedway® Revolution

Speedway® Revolution is a stationary, small form factor, UHF Gen 2 RFID tag reader that provides network connectivity between tag data and enterprise system software. Built with the same industry-leading quality, high performance, and excellent reliability of Impinj's original Speedway reader, Speedway Revolution offers a variety of new features that increase its application flexibility:

•**Low Power Consumption**
With a low power consumption design, Speedway Revolution is capable of using Power over Ethernet (PoE). Using PoE simplifies deployment and dramatically reduces the costs and greenhouse gas emissions (GHG) of your RFID infrastructure. Even when using PoE, however, Speedway Revolution does not compromise on performance. It delivers the full 30 dBm transmit power. Note that Speedway Revolution supports the IEEE standard 802.3af (for PoE).

- **Compact Form Factor**
  The compact size of Speedway Revolution (7.4 x 6.9 x 1.2 in) eases installation in tight spaces and embedded applications.

- **Availability of Two Models**
  Impinj offers two Speedway Revolution models, with different high performance monostatic (transmitter and receiver utilize the same port) antenna port configurations. The R220 model is a two-port configuration, while the R420 is a four-port configuration (shown in the above photograph).

- **High Performance Features**
  Speedway Revolution utilizes a variety of high performance features making it possible to read more than 1100 tags per second. These features include Autoset, Low Duty Cycle, dynamic antenna switching, inventory search modes that improve tag population management, and receive sensitivity filtering for read zone confinement.

- **Ease of Use Features**
  Speedway Revolution uses industry-standard application interfaces, simplifying its integration with RFID middleware or custom software solutions. In addition, it offers enterprise-class management and monitoring capability.
- **Robust Reader Design**
  Just like its Speedway predecessor, Speedway Revolution uses a single circuit board design that delivers field-proven, enterprise-class quality and reliability.

Requirements for Using Speedway Revolution

This section describes the key requirements for operating and interfacing with a Speedway Revolution reader.

Environmental Requirements

- Operating temperature: -20º C to +50º C (non-condensing)
- Supported Regions: US, Canada, and other regions following US FCC Part 15 regulations; European Union and other regions following ETSI EN 302 208 v1.2.1 without LBT regulations

Hardware Requirements

- TCP/IP network equipment, as required to connect the reader to a PC, Mac, or other network terminal. If you plan to use PoE, you must have either a power injector or a network switch that supports PoE.
- Impinj-approved UHF RFID antenna(s), including associated RF cable(s) with RP-TNC male connector interface
- A computer running Microsoft Windows XP, Vista, or Linux PC, which has:
  - an available RS-232 serial port
  - a Cisco Management Cable (RJ-45 to DB9)—to communicate over serial
  - An Ethernet port
  - Standard Ethernet cable(s)

Note: To use the MultiReader application (see page 13), you must be running Microsoft Windows XP.

Power Requirements

As noted earlier, there are two options for powering your Speedway Revolution reader: Power-Over-Ethernet (PoE) or an external universal power supply. PoE offers the most efficient power consumption and supports up to +30 dBm. An external universal power supply supports up to +32.5 dBm. Operating at +32.5 dBm requires professional installation. See "Appendix A: Information Specific to Regions of Operation" on page 27 for details.

If using a universal power supply module, you must use a module with +24 VDC output that has the following part number: **IPJ-A2001-000**. Use AC power cords with either of the two part numbers: **IPJ-A2051-USA** (for North America) or **IPJ-A2051-EU1** (for European Union). You can order the universal power supply and power cords from Impinj.

Supported Operating Environments

This section describes the environments in which you can access the Speedway Revolution Rshell console (for configuring, monitoring, and maintaining the reader). The tools you use to access the Rshell console depend on how you connect your PC to the reader: serial connection (RS-232) or Ethernet connection (SSH/Telnet). On PCs running Microsoft Windows, you can now use the same tool—Putty—for both types of connections.

Table 1: Speedway Revolution Operating Environments

Interface	Protocol	Recommended Tools	
		Microsoft Windows	**Linux**
Ethernet	SSH—Port 22 Telnet—Port 23	Putty[1]	SSH or Telnet
Serial	RS-232	Putty (version 0.60 and higher supports serial)	Minicom

1. (http://www.chiark.greenend.org.uk/~sgtatham/putty/)

Supported Communication Protocol

For client control of the reader, Speedway Revolution supports the EPCglobal Low Level Reader Protocol (LLRP) v1.0.1. LLRP is an EPCglobal standard interface that allows communication with the reader and with EPCglobal Gen 2 RFID tags.

Antenna Requirements

Depending on the reader model you are installing, Speedway Revolution is equipped with two (R220) or four (R420) monostatic antenna ports (independent, bidirectional, and full duplex TX/RX).

Antenna requirements vary by regulatory region. For details about the requirements in a specific region, see the relevant antenna section in "Appendix A: Information Specific to Regions of Operation" on page 27.

Chapter 2: Installing and Connecting Speedway Revolution

This chapter provides details about the Speedway Revolution I/O ports and status LEDs, and explains how to install the reader and connect it to your network.

Speedway Revolution Ports and LEDs

The following graphic illustrates the various I/O ports located on the Speedway Revolution reader. This graphic illustrates a Speedway R420, which includes four antenna ports (not visible in this view). Note that Speedway R220 includes two antenna ports. Other than that difference, however, the exterior ports are the same on both models.

Figure 1: Speedway Revolution Port Connections
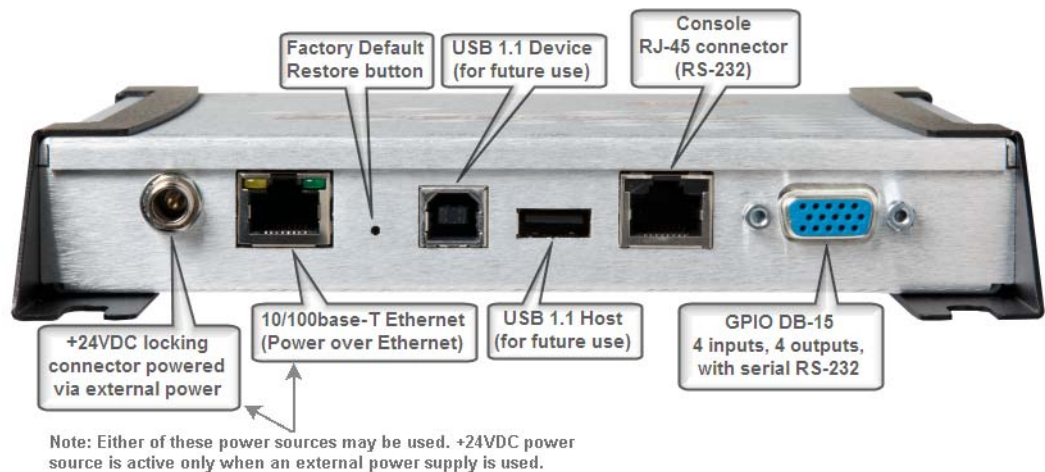
Note: For details about the function and electrical specifications for each pin of the GPIO DB-15 connector, see "Appendix B: GPIO Details" on page 31.

On the back side of the reader are the antenna ports and LED status indicators. The following graphic (of an R420) illustrates their locations:

Figure 2: Speedway Revolution Antenna Ports and Status LEDs

The following table describes the LED behavior for various reader states:

Table 2: Reader Operations and Associated Status LED Behavior
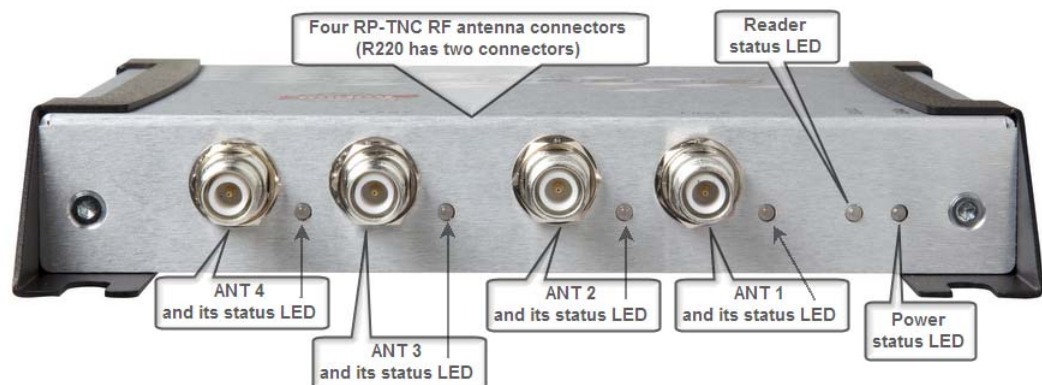
Reader Operation		LED	Expected Behavior
Startup (power on), normal completion	Power applied, attempting to start boot code	Power	Solid red
		Status	Off
	Bootloader calling firmware image	Power	Solid green
		Status	Off
	Bootloader completed successfully, reader is ready	Power	Solid green
		Status	Solid green
Startup (reset), normal completion	Factory Default Restore (FDR) button pressed	Power	Turns off
		Status	Off
	FDR button pressed for 3 seconds	Power	Blinks once (red), indicates a configuration default restore will occur
		Status	Off
Startup (failure)	Hardware problems detected, unable to boot	Power	Continuous blinking red
		Status	Off
Upgrade activity	Upgrading the firmware during boot process	Status	Alternates between red and green
Detection of antenna activity	Detects no activity on antenna port	Antenna	Off
	Detects antenna transmission activity on antenna port	Antenna	Solid green
Inventory activity	Performing an inventory operation	Status	Blinks orange, blinks faster as tag volume increases
LLRP activity	Active LLRP connection	Status	Double blink pattern (green)
LLRP activity	Disconnected operation	Status	Single blink pattern (green)

Installing and Connecting the Reader

Listed below are the primary steps to follow to install and connect Speedway Revolution:

1. Position the reader appropriately for your environment. This may or may not involve mounting the reader.
2. Connect the antenna(s) to the appropriate ports on the reader.
3. Connect the reader to the network.
4. Connect power to the reader.
5. Test the reader installation by reading some tags.

Detailed Installation Procedures

This section provides the details for each step listed above.

Step 1: Position the Speedway Revolution Reader and (optionally) Mount the Reader

Choose the appropriate location for the reader. Generally speaking, you should always keep the unit away from direct sunlight, high humidity, extreme temperatures, vibration, and sources of electromagnetic interference. Any combination of these conditions may degrade performance or shorten the life of the unit. Because the Speedway reader supports Power over Ethernet (PoE), it can obtain its electrical power along with data via standard cable in an Ethernet network. To minimize power loss, it is best to position the reader within 100 meters of its power source. Or, if you plan to power the reader using an external universal power supply, confirm that there is a standard 120 or 220 VAC outlet nearby.

Depending on your environment, you may need to mount the reader to a wall or another object.

To mount the Speedway Revolution reader:

1. Locate the four mounting slots on the reader, as illustrated below:
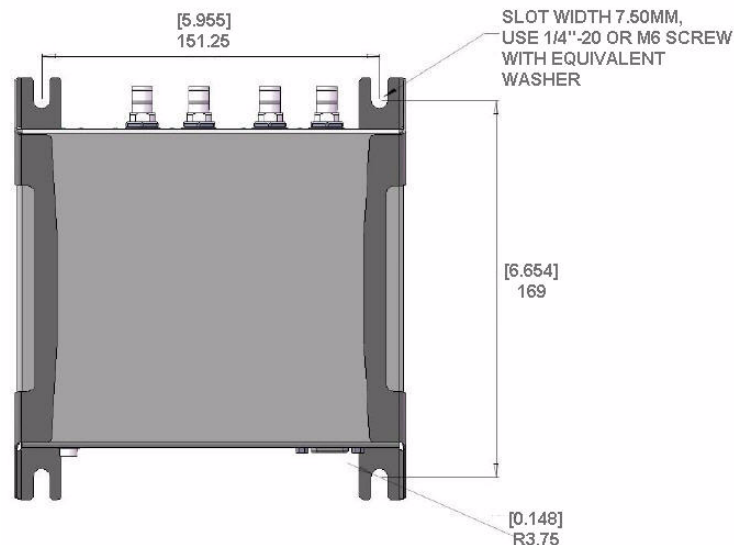
2. Using 1/4" - 20 or M6 screws, secure the unit. You can mount the reader horizontally or vertically.

Caution: If there is any chance of dust or water exposure, you should mount the reader so that digital I/O ports are facing down to prevent ingress.

Step 2: Connect the Antenna(s) to the Speedway Revolution Reader

Depending on the Speedway Revolution model you are installing, the reader has either two antenna ports (R220) or four antenna ports (R420). Each port is independent, bidirectional, and full duplex TX/RX (monostatic).

⚠ Warning: You must use Impinj-approved antennas with Speedway Revolution. See "Appendix A: Information Specific to Regions of Operation" on page 27 for a detailed list of approved vendors. Using any other antenna may adversely affect performance or damage the reader. Speedway Revolution requires professional installation to correctly set the TX power for the RF cable and antenna selected.

To connect the antenna(s) to Speedway Revolution:

1. Position each reader antenna, keeping the following points in mind:
   - Position the antenna(s) to achieve the most effective and efficient tag reads.
   - Position the antenna(s) to maximize operator safety. Personnel who will be in the area for prolonged periods of time should be able to remain at a safe distance at all times. See "Appendix A: Information Specific to Regions of Operation" on page 27 for the specific requirements for your regulatory region.

2. Mount the antenna(s) according to the instructions provided by the antenna manufacturer.
3. Attach the antenna cable(s) to the antenna port(s) on the reader. You can choose any port for any antenna.
4. Finger-tighten each connection, making sure it is secure. A loose connection negatively impacts the performance of the antenna. The antenna cable is properly tightened when you are no longer able to twist the cable inside the connector.

Caution: Impinj has designed the Speedway Revolution antenna ports to be self-terminating. Therefore, it is important that you do not terminate unused antenna ports. Leave them unconnected.

Step 3: Connect Speedway Revolution to the Network

You are now ready to connect the installed Speedway Revolution to your network. You have two options:

- If your network supports DHCP, you can connect the reader directly to your Ethernet network and, once the reader is powered, immediately communicate with it via Telnet (TCP/IP).
- If your network does not support DHCP, you will need to connect a PC directly to the reader using a serial connection (RS-232), then use the reader's Rshell command line interface to configure a static IP address for the reader. At that point, you will be able to connect the reader to your Ethernet network.

The details of completing each connection option are discussed below. Before proceeding, however, take note of the reader's factory default network settings:

Table 3: Default Network Settings

Setting	Description
hostname	SpeedwayR-XX-XX-XX where XX-XX-XX is the last three bytes of the reader's MAC address (which is printed on the version label attached to the reader enclosure)
DHCP	Enabled. The reader also reports its hostname to the DHCP server.

To connect Speedway Revolution to the Ethernet network:

•   Using a standard Ethernet cable, connect the RJ-45 connector on the reader to a LAN drop or network switch. A typical network configuration is illustrated below:
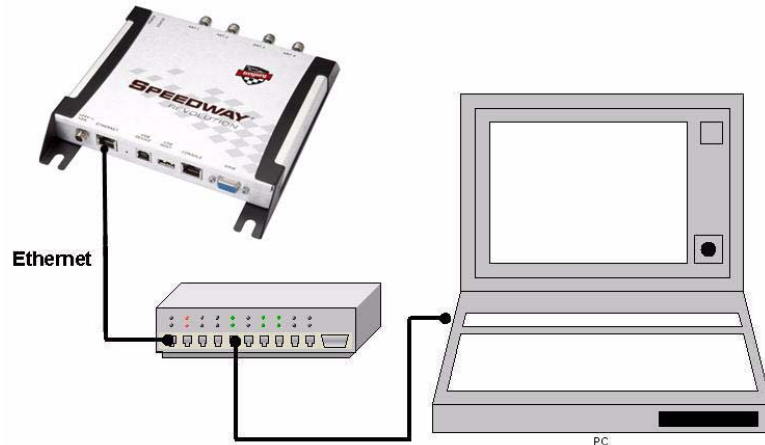
If your network switch is PoE-enabled, the reader will power on when you connect it to the network. See "Step 4: Power the Reader" on page 11 for information about what to expect.

Note: If you need to connect a PC directly to the Ethernet port, you can use a standard Ethernet cable. A crossover cable is not necessary.

To connect Speedway Revolution to your PC over a serial connection:

1. If necessary, download the latest version of Putty, which is a free and reliable SSH, Telnet, and serial client. Version 0.60 or higher contains support for serial connections.
2. Using a Cisco management cable (RJ-45 to DB9, available from Impinj with a part number of IPJ-A4000-000), connect your PC's valid/active COM port to the serial port on the reader, as illustrated below:
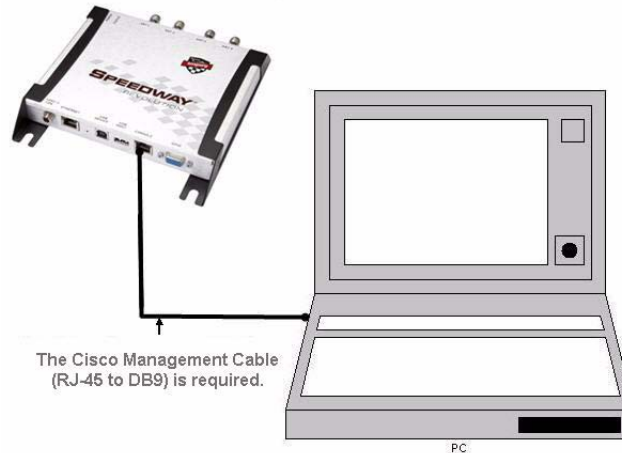
3. Power the reader and wait for the boot sequence to complete. (See "Step 4: Power the Reader" on page 11.)
4. On the PC, run the Putty application and select the **Serial** connection option. Verify that **Serial line to connect to** is set to **COM1** (if that is correct for your PC). Set **Speed** to **115200**. Set **Flow control** to **None**.
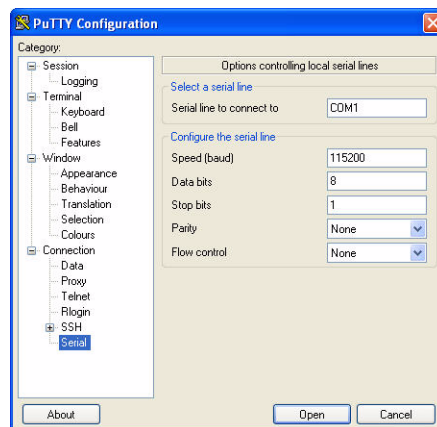
5. Click **Open**. The Rshell console window opens.
6. Press Enter. The Rshell login prompt appears.
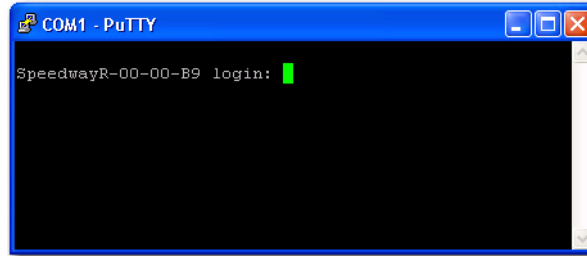
7. Log in with the following default credentials (unless they have been changed):

```
User Name:  root
Password: impinj
```

8. When the Rshell command line prompt appears, you can begin configuring the network settings for the reader. See "Using Rshell to Configure Network Settings for Speedway Revolution" on page 12 for details.

9. When you have completed configuration of the appropriate network settings, connect the reader to your Ethernet network as described on page 9.

Note: If you decide to connect to DHCP after connecting serially, remember to use Rshell to change the IP address on the reader from static to dynamic. See "Using Rshell to Configure Network Settings for Speedway Revolution" on page 12 for details.

Step 4: Power the Reader

You have two choices for powering Speedway Revolution:

• Power over Ethernet (PoE)
• External universal power supply

If you are using PoE, your reader began receiving power when you connected it to the network in the previous step. Therefore, there is nothing more you need to do. If you are using an external universal power supply, connect the AC power plug into a suitable 100-240 VAC, 50-60 Hz power outlet.

In either case, when power is supplied to the reader, it begins its boot sequence. This sequence typically completes within 30 to 45 seconds. Until the boot sequence completes, the reader will not accept commands. The Power and Status LEDs on the reader alert you to what is happening. See Table 2 on page 6 for details.

Important: If a reader is receiving its power via PoE and it detects that an external universal power supply has been connected, the reader reboots and switches its power source from PoE to the external universal power supply. If, however, the reader is receiving power via an external universal power supply and it detects the connection to a PoE-enabled network switch, nothing changes. The reader continues to receive its power from the external supply. Because the external universal power supply is capable of higher power than PoE, it always takes precedence if both sources are connected.

Step 5: Test the Installed Reader

To test that everything is connected and functioning properly, try reading some tags. The easiest and quickest way to verify operation is by using the MultiReader application, a test application from Impinj that is useful for quickly configuring various reader parameters and running simple inventory operations. For details about how to access and use MultiReader, see page 13.

Chapter 3: Configuring and Monitoring Speedway Revolution

This chapter provides a high-level view of the configuration and monitoring options available for Speedway Revolution.

Configuring Speedway Revolution

You can think of Speedway Revolution configuration in two categories: configuration of the device itself and configuration of the reader's RF behavior. This chapter provides the basics for each type of configuration.

Device Configuration

To configure and manage network settings, firmware upgrades, and other device-oriented operations, you use Rshell, a proprietary command line management interface. This chapter introduces the Rshell commands you are most likely to need when initially installing and connecting the reader. You can find full details and syntax for all Rshell commands in the *Rshell Reference Manual*.

Note: Rshell is designed to be a machine interface. As such, it is always backward-compatible with previous Speedway Revolution versions. Existing inputs and outputs will never change. New commands may be added, however, as well as new optional arguments (which will always be added at the end).

Important: The Speedway Revolution version of RShell is NOT compatible with the original Speedway reader.

Using Rshell to Configure Network Settings for Speedway Revolution

The default configuration settings in Speedway Revolution are often enough to get you up and running with little to no configuration required. In some cases, especially if you are not using DHCP to assign IP addresses, you will need to configure a few of the reader's network settings.

The following procedure outlines the Rshell commands you may need for connecting the reader to your network.

To configure the reader's network settings:

1. Open the Rshell console (see page 10 for details).
2. View the reader's current configuration settings by issuing the `show network summary` command at the Rshell command prompt:

```
> show network summary
Status='0,Success'
PrimaryInterface='eth0'
ActiveInterface='eth0'
Hostname='SpeedwayR-00-00-B9'
connectionStatus='Connected'
ipAddressMode='Dynamic'
```

```
ipAddress='10.0.10.41'
ipMask='255.255.0.0'
gatewayAddress='10.0.0.10'
broadcastAddress='10.0.255.255'
```

3. Configure the appropriate TCP/IP parameters for your environment. The applicable commands are outlined below:

    •   **Setting Hostname**

        ```
        > config network hostname <HOSTNAME>
        ```

    •   **Setting Static IP Address**

        ```
        > config network ip static <IP ADDRESS> <NETMASK> <GATEWAY>
        <BROADCAST>
        ```

        Note that, except for the IP address, the other parameters are optional. If an optional parameter is omitted from the ip command, its default value is used.

    •   **Enabling DHCP**

        ```
        > config network ip dynamic
        ```

    •   **Configuring NTP Servers**

        ```
        > config network ntp add <NTP SERVER ADDRESS>
        ```

4. After successfully configuring all required network settings, you can connect the reader to the network via the Speedway Revolution Ethernet port.

RF Configuration

The approach you use to configure the reader's RF behavior depends entirely on your implementation. You may be using a custom software application, middleware running on a server, or some other approach. MultiReader (see below) is an example of such a client application. Regardless of the application you're using, however, the underlying protocol is the same—Low-Level Reader Protocol (LLRP), a standard, asymmetric, binary protocol used for communication between a client application and the reader. LLRP controls configuration of such things as the antenna transmit power and receive sensitivity, the mode in which the reader should operate, and more. For details about LLRP, see one or more of the following documents:

*   *LLRP Standard*: http://www.epcglobalinc.org/standards/llrp/llrp_1_0_1-standard-20070813.pdf—This document provides the specifics of the EPCglobal-ratified LLRP standard.
*   *Octane LLRP (Revision 4.2)*—This document provides the details of the LLRP capabilities supported by Speedway Revolution. It also describes the custom LLRP extensions added by Impinj.
*   *Impinj LTK Programmer's Guide*—This guide, intended for software engineers, provides guidelines and best practices for working with the LLRP Toolkit. In addition, software engineers can access language-specific reference guides and sample applications illustrating the scenarios discussed in the Programmer's Guide.

## Using MultiReader to Configure and Test Speedway Revolution

Impinj provides a simple, easy-to-use LLRP application for configuring and testing the basic RF behavior of Speedway Revolution. This application, called MultiReader, is available from the Impinj support Web site (support.impinj.com). To use MultiReader, your

computer must be running Microsoft Windows XP. MultiReader is recommended for test purposes only.

This section explains how to use MultiReader to connect to and configure a reader's RF parameters. It also provides a high level description of each parameter.

To configure and test a reader from within MultiReader:

1. Install and launch the MultiReader application. The following screen appears:
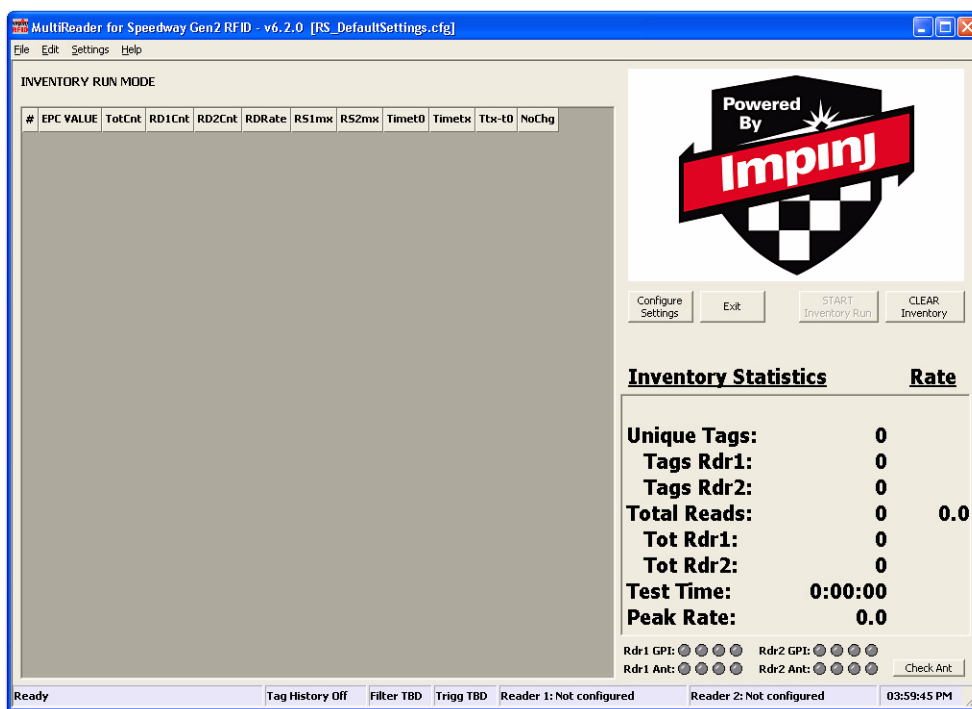
2. Click **Configure Settings**. The **Reader Settings** screen appears:
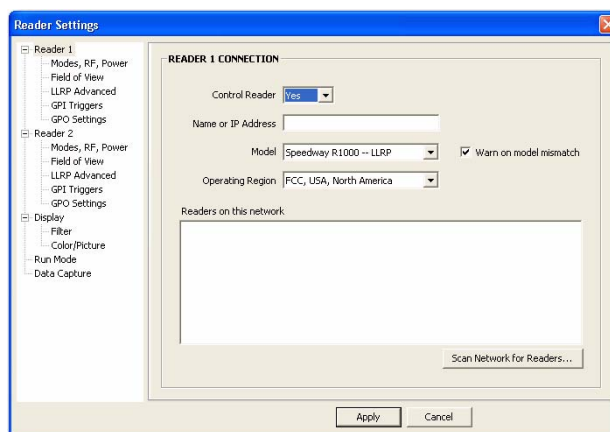
3. Connect to the reader by doing the following:
   - In **Name or IP Address**, type the reader's IP address (or host name). You can determine the name and the IP address via the Rshell `show network summary` command.

Note: The `show network summary` command will provide the dynamic values returned by DHCP or LLA if the current configuration is dynamic. The local hostname resolution feature (mDNS) gives the reader a local hostname in addition to an IP address as its network

identity. On an isolated network that lacks DNS service but has mDNS enabled, a reader with hostname speedway-00-01-02, for example, may be reached using speedway-00-01-02.local.

- In **Model**, select the appropriate Speedway Revolution model (either Speedway R220 or Speedway R420). If you want MultiReader to issue a warning if it detects a model other than what is configured, select the **Warn on model mismatch** checkbox. It is selected by default.

4. Configure a few key RF parameters as described below:
   - Under **Reader 1** (in the list of readers on the left side), click **Modes, RF, Power**. The following screen appears:
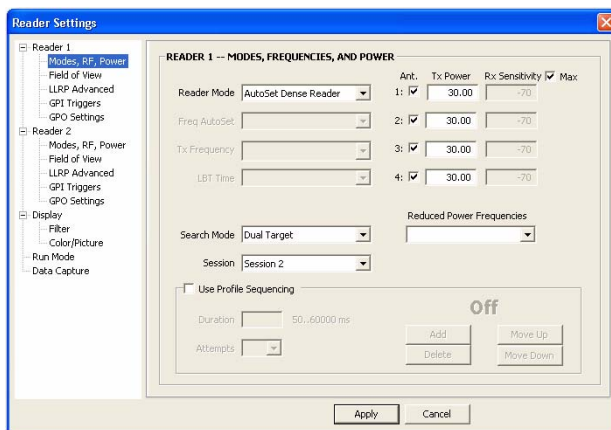
- In **Reader Mode**, select **AutoSet Dense Reader**. The Reader Mode specifies the rules to use for communication between the reader and tag. With AutoSet Dense enabled, the reader automatically senses the environment and adjusts its mode accordingly.

- In **Search Mode**, select **Dual Target**. In **Session**, select **Session 1**. Search Mode and Session work together to control when and how often the reader reads a tag.

  Here is a very high level description of how it works: Each tag contains a flag that is flipped from A to B or from B to A when it is read. The Session value controls how long the flag retains its value before reverting back to its original value. Search Mode controls which flag values the reader reads and, in some cases, what happens to the flag value once the tag has been read. With Dual Target, the reader reads all the tags with A flags, flipping each one to B after it has been read. When there are no more A tags to read, the reader reads all the B tags, flipping each one to A after it has been read. It continues this process back and forth from A to B and back to A. Session 1 ensures a persistence period that prevents tags from reverting before they have all been read.

- On the right of the screen is a checkbox for each of the reader's antenna ports. By default, they are all enabled. Disable any port to which no antenna is connected (in other words, deselect the checkbox). Note that leaving all the ports enabled does no harm, but it does waste processing time because the reader hops to all enabled ports, verifying the presence of an antenna before attempting to activate it.

- For each enabled antenna, set the appropriate transmit power (**Tx Power**) and receive sensitivity (**Rx Sensitivity**).

    Transmit power controls the power of the signal leaving the antenna—and thus controls the range of the signal. The optimal setting depends on many things: how you are powering the reader, the cable length connecting the antenna to the reader, the number of antennas in the area, the anticipated distance between the antenna and the tags, and more. For testing purposes, you may want to use the default value of 30 dBm. Note that the maximum configurable value is 32.5 dBm (if using an external power source).

    Receive sensitivity controls the tag signal threshold below which the tag is ignored by the reader. This parameter is useful in mitigating stray reads (as stray tags often have a weaker signal than the tags that are intended to be read). By default, the **Max** checkbox is selected, which tells the reader to read all tags, regardless of the tag's signal strength (also known as its Received Signal Strength Indicator—or RSSI). If you want to configure a specific receive sensitivity, deselect the **Max** checkbox and type the value you want for each connected antenna. Note that maximum sensitivity is -80.

    Keep in mind that, for now, you are simply configuring the reader to test your installation. You can always adjust these settings later when you begin using the reader in a live RFID operation.

5. Click **Apply**. MultiReader displays a progress bar as it connects to the reader. When the connection completes, the following status appears at the bottom of the application:
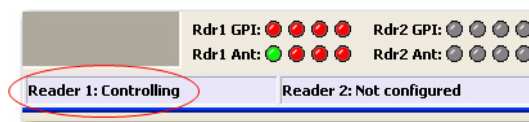
6. It's now time to test your reader installation. Place one or more tags in the read zone of one or more of the attached antennas. Click **START Inventory**. Tag reads appear in the large gray area on the left:

#	EPC VALUE	TotCnt	RD1Cnt	RD2Cnt	RDRate	RS1mx	RS2mx	Timet0	Timetx	Ttx-t0	NoChg
1	3008-33B2-DDD9-06C0-0002-0017	355	355	0	16.2	-66	---	0.000	21.846	21.846	2
2	3008-33B2-DDD9-06C0-0002-000B	355	355	0	16.2	-41	---	0.000	21.846	21.846	2
3	3008-33B2-DDD9-06C0-0002-0004	355	355	0	16.2	-58	---	0.000	21.846	21.846	2
4	3008-33B2-DDD9-06C0-0002-000D	293	293	0	13.4	-67	---	0.000	21.846	21.846	1
5	3008-33B2-DDD9-06C0-0002-0005	112	112	0	5.5	-68	---	0.483	20.831	20.347	13

    In this case, the reader detected five tags. Because the search mode is Dual Target, the reader continuously reads the tags (first reading the A flags, and then reading the B flags). Notice in the above image that one of the tag entries is a pinkish color. When a tag is not being actively read, its entry begins changing to red. For example, if you were to change the Search Mode to Single Target with Suppression (which tells the reader to read a tag only once), all five entries would quickly turn red and stay red:

So what is the bottom line? If you see tag data appearing in MultiReader, your reader is most likely installed correctly and its antennas are functioning properly. If you don't see all the tags that you placed in the read zone, try moving them to a slightly different location or placing them in a different orientation.

7. To stop the tag inventory, click **STOP Inventory Run**.

Monitoring Speedway Revolution

When Speedway Revolution is up and running, you can use Rshell to monitor its health and performance. This section presents the primary Rshell commands to use for viewing network and RFID statistics as well as the reader logs. For details about these commands, see the *Rshell Reference Manual*.

Octane 4.2 adds support for SNMP and EPCglobal Reader Management MIBs. For more information, see the *Octane SNMP Guide.*

Viewing Network Parameters and Statistics

Use the Rshell `show network` command to display networking parameters and statistics. Using this command (along with the indicated parameters), you can view the following information:

Table 4: show network Command Parameters

Parameter	Displayed Information
dhcp	Summary of DHCP client configuration
dns	Summary of DNS settings
icmp	ICMP statistics
ip	IP statistics
ntp	Summary of NTP settings
summary	Summary of network settings
tcp	TCP statistics
udp	UDP statistics

For details about the specific settings and statistics available for each of these parameters, see the *Rshell Reference Manual*.

Viewing RFID Parameters and Statistics

Use the Rshell `show rfid stat` command to display a reader's RFID parameters and statistics. Using this command (along with the appropriate parameter), you can view such information as:

Table 5: Partial Listing of show rfid stat Parameters

Parameter	Displayed Information
`ReaderOperationalStatus`	Indicates whether RFID applications are running on the reader
`Antenna<n>OperationalStatus`	Indicates if an antenna is physically connected to the reader and operating properly. Note that <n> indicates the antenna port on the reader (1-4).
`Antenna<n>EnergizedTime`	Indicates the time that antenna<n> has been powered, in milliseconds.
`Antenna<n>UniqueInventoryCount`	Indicates the number of unique tags seen at antenna<n>
`Antenna<n>TotalInventoryCount`	Indicates the total inventory count for antenna<n>
`Antenna<n>ReadCount`	Indicates the number of tags read at antenna<n> that matched the configured filters.
`Antenna<n>FailedReadCount`	Indicates the number of tags where a read was attempted at antenna<n> because the tag matched the configured filter, but the read failed.

Table 5 shows just a few of the RFID statistics available. For the full list as well as syntax details, see the *Rshell Reference Manual*.

Note: You can also view statistics on the LLRP interface between the reader and a client by entering the `show rfid llrp` command. See the *Rshell Reference Manual* for details.

Configuring and Viewing Speedway Revolution Logs

Speedway Revolution uses the standard Syslog protocol to forward its logged events to a remote Syslog server. The reader also stores the logged events in its filesystem, accumulating and persisting this information across reboots. Logs are classified into three categories: Management, RFID, and System.

All logged events have an associated severity level. There are eight possible levels which are listed below in decreasing order from most severe to least severe:

- Emergency
- Alert
- Critical
- Error
- Warning
- Notice
- Info
- Debug

You can configure the log levels you want to see. The reader then retains only the events with a severity greater than or equal to the configured level. For example, if you choose a logging level of Warning, then the logs will contain the following levels: Warning, Error, Critical, Alert, and Emergency.

Note: Regardless of the configured log level, the reader retains all Error level logs (and higher) in an independent error log.

Use the Rshell `config logging` command to configure options for the storage and forwarding of logged events. Use the `show logging` command to display the logging configuration as well as the actual logged information (in text form). For details about these commands, see the *Rshell Reference Manual*.

Viewing the State of the Speedway Revolution Device

To display information about the current state of the reader itself, use the Rshell `show system` command. Using this command, you can view the following statistics:

- A summary of system information—`show system summary`
- Platform memory usage and available application space—`show system cpu`
- Generic platform statistics—`show system platform`

For more details about the `show system` command, see the *Rshell Reference Manual*.

Chapter 4: Upgrading the Speedway Revolution Firmware

Speedway Revolution contains firmware (known as Octane) which you may periodically want to upgrade. This chapter explains how to manually upgrade a single reader.

In addition to supporting upgrade procedures, Speedway Revolution also provides methods for reverting its firmware to a previous valid image and for restoring its firmware to factory default settings. The procedure for reverting to the previous image is explained in this chapter, while returning to factory defaults is explained on page 23.

A Brief Overview of the Speedway Revolution Firmware

To minimize downtime and maximize the robust handling of possible upgrade failures, Speedway Revolution contains dual images of its firmware. When an upgrade is requested, the reader continues to operate using the primary image while, in the background, it upgrades the secondary image. When the upgrade completes, the reader reboots to the new upgraded image, but retains the previous firmware version on the other image. This approach makes it easy to revert to the previous working version in case there are any problems with the upgraded image.

Within each firmware image are three individual partitions that logically organize the system software. Although you do not need a full understanding of this architecture to perform a simple manual upgrade, it is a good idea to be familiar with its structure at a high level. For a more in-depth discussion of the firmware and how it is organized, see the *Embedded Developer's Guide*.

Following are high-level descriptions of the firmware's three partitions:

- **System Operating Partition (SOP)**—The SOP is the primary system partition of the Speedway Revolution reader. It contains the Linux kernel, the FPGA firmware, the RFID management software, the reader management software (Rshell), the logging management software, the firmware upgrade control, the system watchdog software, and the factory default data.
- **System Persistent Partition (SPP)**—Files in this partition are automatically generated and maintained by the software running on the reader. It contains the reader configuration (network settings, LLRP configuration, log settings, and so on), reader logs, and debug information used by Impinj engineers.
- **Custom Application Partition (CAP)**—This partition contains custom application software, other items required by the custom application (extra libraries or tools, configuration files), and custom application logs.

Upgrading the Firmware

Speedway Revolution provides two methods for upgrading the firmware—manual and automatic. The manual method, which is accomplished by issuing commands from within

the Rshell console, is best for upgrading individual readers. The automatic method, which involves the use of an upgrade configuration file called a metafile, is useful for automating the upgrade of a large number of readers. As previously mentioned, the focus of this guide is the manual method.

To upgrade the Speedway Revolution firmware:

1. Obtain the firmware upgrade file from the Impinj support Web site (support.impinj.com). The upgrade file always has an extension of `.upg`.

2. Place the upgrade file on a server (http, tftp, or ftp) that is accessible by the reader you are upgrading.

3. Using the putty application, connect and log in to the reader.

4. From the Rshell command prompt, issue the following command:
   ```
   >config image upgrade <URI>
   ```
   where <URI> is the server location and name of the upgrade file.
   For example:
   ```
   >config image upgrade http://usacorp/rfid/reader/image/
   OCTANE_4_0_0.upg
   ```
   ```
   >config image upgrade ftp://anonymous:abc@myserver/
   ftpdirecotry/image_4_2_0.upg
   ```
   ```
   >tftp://server/sop_3_2_1_RC5.upg
   ```

1. After starting the upgrade, you can view the upgrade status at any time by issuing the following command:
   ```
   >show image summary
   ```

   This command provides the current upgrade status, the last operation, the status of the last operation, and information about the primary and secondary images. You can continue to reissue the `show image summary` command if you want to keep an eye on the upgrade status. Some of the status values you may see are:

   ```
   WaitingForImageFileTransfer
   WaitingForCommitImage
   WaitingToActivateImmediate
   ```

   The upgrade is complete when the UpgradeStatus parameter value is `Ready`. The LastOperation parameter should be `WaitingToActivateImmediate` and the LastOperationStatus should be `Waiting for manual reboot`.

2. Reboot the reader by issuing the following command:
   ```
   >reboot
   ```
   Speedway Revolution goes through its reboot process, displaying messages in the Rshell console as it goes through each stage of the process. When the reboot completes, the reader login prompt appears on the console and the status light on the reader is solid green. (See page 6 for details about the LED behavior to expect when the reader is booting up.)

3. Log in to the reader.

To fall back to the previous image

1. If you need to revert to the pre-upgrade image, simply issue the following command from the Rshell prompt:
   ```
   config image fallback
   ```
   When the command completes successfully, the reader reboots automatically and returns to the login prompt.

2. Log in to the reader. It is now running the pre-upgrade image.

Note: If there is no valid previous image, the response to the `config image fallback` command is `Status='8,Permission-Denied'`.

Chapter 5: Troubleshooting

This brief chapter presents a few suggestions of things to try if you experience problems with Speedway Revolution.

Returning to the Factory Default Configuration

If you are experiencing problems with the reader and are having difficulty pinpointing the cause, it is often useful to return the reader to a known state (in this case, the factory default configuration) and try again.

Important: Factory Default <u>Configuration</u> Restore returns the reader configuration to its default state, but leaves any custom applications installed in the CAP intact. To restore the reader to its default state AND remove any CAP contents, use Factory Default Restore. See "Warning:" on page 23.

There are two ways to return Speedway Revolution to its factory default configuration—issuing an Rshell command or pushing the Factory Default Reset (FDR) button on the device itself.

To use Rshell to return the reader to its factory default configuration (leaving CAP intact):

1. At the Rshell prompt, issue the following command:
    ```
    config image default
    ```
    When the command completes successfully, it automatically reboots the reader and returns to the login prompt.

2. Log in to the reader. It is now running with its factory default configuration.

To use the FDR button on the reader to restore to its factory default configuration:

1. Using an object with a sharp tip (for example, a paper clip), press the FDR button on the back of the reader (while applying power). When the Power LED turns off, wait for 3 seconds (while watching the Power LED). When you see the LED blink red once (this should occur at 3 seconds), release the FDR button. At this point, the reader will boot up normally.

Insert sharp point here for 3 seconds.
Release before 10 seconds.

⚠ Warning: Pressing the FDR button for longer than 3 seconds can cause a factory default restore to occur. Unlike a factory configuration restore, the factory default restore removes

the reader's custom application partition (CAP), if one exists, returning the unit to its state as shipped from the factory. Although there may be situations in which this removal is necessary, it's important to avoid accidentally removing the CAP.

The following table lists the factory default configuration values:

Table 6: Factory Default Configuration Values

| Parameter	Default Value
User	root
Password	impinj
Upgrade Retrieve Mode	Manual
Logging	No syslog servers
Management Logging Level	Error
RFID Logging Level	Error
System Logging Level	Error
Network Mode	Dynamic (DHCP)
DHCP Send Hostname	On
DHCP User Class	None
Hostname	speedwayr-xx-xx-xx (where xx-xx-xx are the last three digits of the MAC address)
Static DNS Servers	None
Static NTP Servers	None
LLRP Inbound Port	5084
LLRP Inbound Service	Enabled
LLRP Outbound Service	Enabled
LLRP Outbound Servers	None
LLRP Outbound Retry Secs	5
LLRP Outbound Timeout Secs	2

Submitting Diagnostic Data for Analysis by Impinj Technical Support

If Speedway Revolution is exhibiting RF behavior that differs from what you expected and you are unable to determine the cause, you may want to submit relevant data for analysis by Impinj Technical Support. Using the Impinj MultiReader application, you can easily capture data related to the problem scenario (by creating a Reader Diagnostic Data file), which you can send to Impinj.

Note: An alternative is to create a network trace using Wireshark, a free protocol analyzer that you can download from the Internet.

To capture data to a Reader Diagnostic Data file:

1. Open MultiReader and connect to the appropriate Speedway Revolution reader. (See page 13 for details.)

2. Click **Configure Settings** to open the **Reader Settings** screen.

3. Verify that you are viewing the connection settings for Reader 1. If you are not, click **Reader 1** in the menu on the left.

4. In **Control Reader**, select **No**. This setting value tells MultiReader that you do not want the MultiReader configuration controlling the reader. Changing this value is important because you most likely want to capture data for a reader operation that is being controlled by your application. If, however, you want to capture an RF scenario that is controlled by MultiReader, set **Control Reader** to **Yes**.

5. In the menu on the left, click **Data Capture**. The following screen appears:
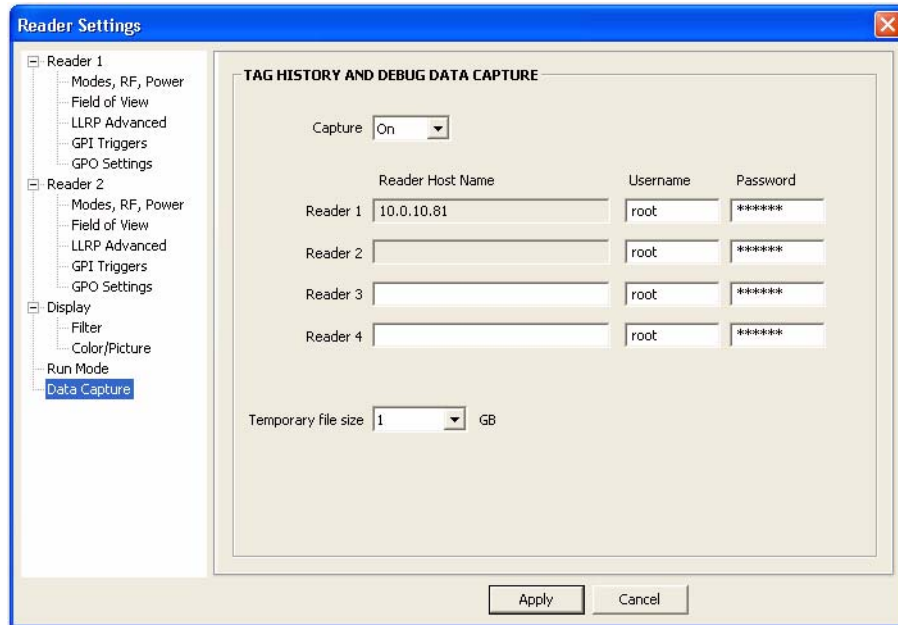
As you can see, Reader 1 is already populated with the IP address. Also note that the login parameters are also populated. If these values are incorrect, you can change them here. Also note that you can capture data for up to four readers simultaneously. In this example, we are capturing data for only one reader.

6. Confirm that **Capture** is set to **On**.

7. Click **Apply**. MultiReader connects to the reader and begins "listening" for any RF activity. At this point, it will capture data surrounding any RF activity it detects.

8. Perform the RF activity that you want to submit for analysis.

9. When you have completed the activity you want to capture, select the **File** menu in the upper left corner of the application.

10. Click **Save Debug Data...**. A browse window opens.

11. Type a name for the file and save it in the desired location.

12. Send the `.rdd` file to Impinj Technical Support. For details about how to submit the file, talk with your Impinj representative or visit the Impinj support Web site (support.impinj.com). Note that this file contains binary data.

Appendix A: Information Specific to Regions of Operation

Speedway Revolution is designed to work in various regulatory regions. This appendix includes frequency ranges and antenna requirements specific to each supported region.

Important: For each region, the reader is locked such that it can operate only in the specific frequencies for that region. The region-specific frequencies are listed in this appendix.

Operation in North America

Frequency Plan

The FCC specifies frequency hopping across the North American spectrum allocated to UHF RFID (902–928 MHz, with hopping occurring between 902.75–927.25 MHz in 500 KHz steps). The frequency plan is further explained in the table below:

Table 7: Frequency Plan for North America

Transmit Channel Number	Center Frequency (MHz)
1	902.75
2	903.25
3	903.75
4	904.25
. . .	. . .
49	926.75
50	927.25

Antenna Requirements

Positioning

Position the antenna such that personnel who will be in the area for prolonged periods of time can remain at least 25 centimeters from the antenna's surface. This positioning is required by the FCC. For more details, see the following FCC bulletins:

- FCC OET Bulletin 65: *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*
- FCC OET Bulletin 56: *Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields*

Installation

Because Speedway Revolution is capable of up to +32.5 dBm conducted power on the housing RF connector, professional installation is required.

Power

Speedway Revolution may only be operated with Impinj-approved antennas and can radiate no more than 36 dBm EIRP per FCC Part 15.247 regulations. The Speedway Revolution output power may be increased to provide the maximum allowable EIRP subject to a maximum conducted power allowance as well. The maximum conducted power at the antenna connector can be no more than 30 dBm. The maximum allowable output power of the reader can be set to satisfy both the conductor and radiated maximum criteria. The expression for the maximum reader power setting is:

Maximum power setting (in dBm)
= The **Smaller** of
(36 - Composite Antenna Gain (in dBm))
OR
(30 + Cable Loss (in dBm)),

where the composite antenna gain comprises the maximum linear antenna gain in dBi minus any cable loss between the reader and antenna in dB. Approved antenna vendors, model numbers, and associated gain are listed in the next section.

Approved Antennas

- Cushcraft model number S9028PCL/R (left- or right-hand CP), with integrated 8 foot pigtail to RP-TNC male connector; 6 dBi composite gain

- Impinj model number IPJ-A0301-USA (Mini-Guardrail) with SMA female connector; -15 dBi gain

- Impinj model number IPJ-A0310-USA (Threshold-T Antenna) with 12 inch integrated pigtail to BNC male connector, 6 dBi composite gain.

- Impinj model number IPJ-A0400-USA, CSL CS-777-2 (Brickyard) with 7 foot integrated pigtail to RP-TNC male connector; 2 dBi composite gain

- Impinj model number IPJ-A0401-USA or IPJ-A0402-USA (both Guardwall) with 6 foot integrated pigtail to RP-TNC male connector; 6 dBi composite gain

- MA/COM MAAN-000246-FL1 integrated RFID floor-mounted stand (multiple configurations available, 2 or 4 antennas left-hand and right-hand CP) with 8 foot integrated pigtail to RP-TNC male connector; 6 dBi composite gain

- MA/COM MAAN-000246-WL1 integrated RFID wall-mounted stand (multiple configurations available, 2 antennas left-hand and right-hand CP) with 8 foot integrated pigtail to RP-TNC male connector; 6 dBi composite gain

- MTI MT-262006/TLH (left-hand CP) or MT-262006/TRH (right-hand CP) with RP-TNC female connector (antennas available in IP54 or IP67 ratings); 6 dBi gain

- MTI MT-262013/NLH (left-hand CP) or MT-262013/NRH (right-hand CP) with N-type female connector (antennas available in IP54 or IP67 ratings); 4.5 dBi gain

- MTI MT-262013/TLH (left-hand CP) or MT-262013/TRH (right-hand CP) with RP-TNC female connector (antennas available in IP54 or IP67 ratings); 4.5 dBi gain

- Sensormatic Electronics Corp. model number IDANT20TNA25 with 25 foot Belden 7806A RG-58 coaxial cable (0.1 dB per foot loss) to RP-TNC male connector; 5.5 dBi composite gain

- Sensormatic Electronics Corp. model number IDANT10CNA25 with 25 foot Belden 7806A coaxial cable (0.1 dB per foot loss) to RP-TNC male connector; 3.5 dBi composite gain

- Sensormatic Electronics Corp. model number IDANT10CNA25 with 6 foot Belden 7806A coaxial cable (0.1 dB per foot loss) to RP-TNC male connector; 5.4 dBi composite gain

⚠Warning: The use of any antenna not listed above may damage the reader or adversely affect performance.

Operation in European Union

Frequency Plan

For European operation, the Speedway Revolution readers support the frequency plan listed in Table 8 and is compliant with the ratified ETSI EN 302 208 specification v.1.2.1. This specification states that no listen-before-talk is performed, the maximum continuous transmit time on a channel is four seconds, and the reader enforces the 100 ms off time before reusing the same channel.:

Table 8: Frequency Plan for European Union

Transmit Channel Number	Center Frequency (MHz)
4	865.7
7	866.3
10	866.9
13	867.5

Antenna Requirements

Power

European regulations allow a maximum radiated power of 33 dBm ERP (Effective Radiated Power) for high power RFID systems. The maximum Speedway Revolution output power is determined by the following equation:

Maximum power setting (in dBm) = 33 – Antenna Gain (in dBd) + Cable loss (in dB)

For example, for an application with an antenna gain of 6 dBd and cable loss of 2 dB, the reader output power can be set no higher than 33-6+2 = 29 dBm. The maximin transmit power of Speedway Revolution is 31.5dBm measured at the RF antenna port. Note that it is important to apply the antenna gain expressed in dBd (dB with respect to a dipole), which is equivalent to the isotropic antenna gain (in dBi) minus 2.15 dB. Additionally, the antenna gain used to set the output power

must be the maximum linear gain of the applicable antenna. Approved antenna vendors, model numbers, and associated gain are listed in the next section.

Approved Antennas

- Cushcraft Model Number S8658PCL/R (left- or right-hand CP) with integrated pigtail to RP-TNC male connector; 3.85 dBd gain

- Impinj Model Number IPJ-A0400-EU1, CSL CS-777-1 (Brickyard) with 7 foot integrated pigtail to RP-TNC male connector; 0 dBd composite gain

- MTI MT-242032/NLH (left-hand CP) or MT-242032/NRH (right-hand CP) with N-type female connector (antennas available in IP54 or IP67 ratings); 1.85 dBd gain

- Sensormatic Electronics Corp. Model number IDANT10CEU25 (left-hand CP only) with 6 foot Belden 7806A coaxial cable (0.1 dB per foot loss) to RP-TNC male connector; 3.25 dBd composite gain

⚠Warning: The use of any antenna not listed above may damage the reader or adversely affect performance.

Appendix B: GPIO Details

Speedway Revolution includes a multipurpose I/O port that contains an RS-232 serial port, four opto-isolated inputs, four opto-isolated outputs, and a +5V supply. You access these features through a DE15 connector mounted on the side of the reader.

The four opto-isolated inputs have a range of 0–30V. The reader treats an input of 0–0.8V as a logic 0, and an input of 3–30V as a logic 1. The reader has a per-input debounce interval that is configurable via LLRP (see the document titled *Octane LLRP* for more information). This value dictates the minimum pulse width of an input. Impinj recommends that external devices guarantee a minimum pulse width of at least 100 milliseconds.

The reader also provides four opto-isolated outputs. For the GPIO outputs to function, an external user supply must be connected between V+, and V-. The maximum voltage for this supply is 30V. When the user configures a selected GPIO output via LLRP to output logic 0, an isolated FET switch within the reader effectively shorts that output to V- with a current sink capability of up to 200mA. When the user configures a selected GPIO output to logic 1, the selected output is pulled to V+ through a 10K resistor. If GPIO isolation is not required, the reader provides a +5V supply and a ground pin on the DB-15 that can be connected to V+ and V-.

Figure 3 shows the detailed function of each pin of the GPIO DB-15 connector.

Figure 3: DB-15 GPIO Port
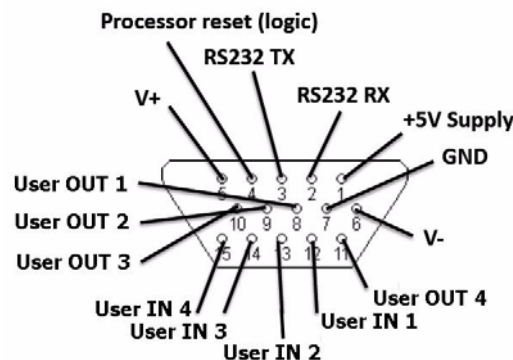
Note: As described above, both the input and output pins are opto-isolated.
Table 9 and Table 10 further explain the function of each pin.

Table 9: DB-15 Connector Pin-Out

Pin	I/O Name	I/O Function
1	+5V Supply	Reader supplied (not isolated) power source
2	RS-232 RX	For auxilliary serial port functions
3	RS-232 TX	For auxilliary serial port functions
4	Processor Reset	Reserved for future use. Do not connect this pin to any signal.

Table 9: DB-15 Connector Pin-Out

Pin	I/O Name	I/O Function
5	V+	Power source for isolated outputs
6	V-	Return for isolated inputs and outputs
7	Ground	Reader (not isolated) return
8	User OUT 1	Isolated output 1 (active pull down to V-)
9	User OUT 2	Isolated output 2 (active pull down to V-)
10	User OUT 3	Isolated output 3 (active pull down to V-)
11	User OUT 4	Isolated output 4 (active pull down to V-)
12	User IN 1	Isolated input 1
13	User IN 2	Isolated input 2
14	User IN 3	Isolated input 3
15	User IN 4	Isolated input 4

Table 10: GPIO Interface Electrical Specification

Pin	Parameter	Description	Min	Max	Unit	Conditions
+5V Supply	I_O	Output current		200	mA	
User IN 1-4	V_{IH}	HIGH level input voltage	3	30	V	
User IN 1-4	V_{IL}	LOW level input voltage	0	0.8	V	
User IN 1-4	I_{LI}	Input current		5	mA	24V input
User IN 1-4	V_I	Input voltage range	0	30	V	No damage
User OUT 1-4	V_{OH}	Output high voltage		V+*	V	10k pullup
User OUT 1-4	V_{OL}	Output low voltage		(V-)+0.5	V	100mA load
User OUT 1-4	V_I	Supply voltage range (V+ - V-)		30	V	

*User-supplied voltage

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